Chapter 11

EVALUATING RAPID TRANSIT

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Throughout most of the world's urbanized areas, public transit needs can be adequately served by local fixed-route bus service operating on streets, mixed with other traffic. Such service is constrained, due to its required stops and delays from other traffic, to average scheduled speeds of 10 to 12 mi/h (16 to 19 km/h). While not competitive with the automobile, these conditions are adequate as long as trip lengths in the corridors served tend to be 5 mi (8 km) or less—about a 30-min trip at average speeds—and maximum hourly passenger volumes in one direction are 5000 to 7000 or less.

Many corridors in larger cities do not fit one or both of these limitations, however, and ways must be found to devise transit service that operates at higher speeds and with higher capacity than local bus service can provide. Provision of express bus service on freeways can sometimes meet the speed requirements, and if no stops for loading are necessary, higher capacity can also be achieved. The acceptable performance range for bus service can often be extended by use of transportation system management (TSM) techniques, which can give buses and other high-occupancy vehicles (HOVs) traffic priority (see Chap. 12). Freeways with bus or HOV lanes or separate HOV facilities provide an opportunity for service at higher speeds and volumes than would be possible in mixed traffic.

On the other hand, reserving lanes for buses, with or without other HOVs, may be physically impractical or publicly unacceptable or may not suffice to meet transportation objectives. Freeways themselves are often congested during peak periods and do not even exist in some corridors. In such situations, strong consideration is often given to the construction of rapid transit.

Rapid transit is defined for purposes of this discussion as express, limited-stop transit service provided entirely or primarily on exclusive or reserved rights-of-way.

Vehicles can be steered by a fixed guideway or by professional drivers, suspended on steel wheels or rubber tires, and propelled by electric motors or petroleum engines. Within rapid transit, there is a choice between rail or bus systems and their variants.

This choice has been made more complex by the increasing opportunity and tendency to opt for "mixed" systems of rail, bus, HOVs, people movers, and so on. It is indeed appropriate to consider the full spectrum of options extending from local transit, through express bus service enhanced by TSM, to semirapid transit and full rapid transit in its various forms. Even so, the decisions and trade-offs for mode selection in any given corridor must still consider the same essential points.

Development costs for rapid transit are always several orders of magnitude greater than for local transit, which benefits from the established street and highway network. Moreover, the high-cost guideways, stations, and maintenance facilities of rapid transit are fixed in place, and thus very careful consideration must be given to their location. They must effectively serve the community for many decades in order to amortize the large investment. All this means that the planning and decision-making process for rapid transit development is much more rigorous, expensive, time consuming, and potentially frustrating than for local transit.

In addition to system location, questions of financing, phasing, performance, social impacts, economic impacts, environmental impacts, and extent of the system must be resolved. Two of the most difficult decisions have to do with:

• Whether rapid transit development should be undertaken at all.

• Which rapid transit mode would be most suitable in the local environment.

WHETHER TO BUILD

In the United States, three primary influences on the decision of whether to embark on rapid-transit development can be identified:

1. Financial and institutional factors—those institutional arrangements that dictate the constraints within which the system is to be financed.

2. Attitudinal factors—those predispositions of the community that exist independent of the plan and planning process associated with rapid-transit development.

3. Physical and analytical factors—those intrinsic attributes that involve the physical layout of the system and the ridership it will serve; its costs, performance, and interaction with other elements of the transportation system; and benefits and cost effectiveness.

These three primary influences structure the following discussion, but not without reference to another division of influences, that of political concerns versus technical concerns. It is unrealistic and therefore detrimental to constructive planning to ignore the influence of political concerns and motives. At the same time, sound, objective, and instructive technical findings are at the heart of good decision making in the high-stakes process of rapid transit planning and development.

FINANCIAL AND INSTITUTIONAL FACTORS

To understand the financial and institutional factors influencing the decision to build or not build a project of the monumental proportions normally included in a rapid transit system, one must have some concept of the motivational context of the agency charged with implementation. This context can be markedly different depending on whether there is an established local/state funding source adequate for the scale of nonfederal funding required. Frequently, there is no adequate funding mechanism in place, and the agency charged with rapid transit construction is also charged with developing the financing.

In one common scenario of this type, which will serve to illustrate the interplay that can arise, the substantive beginning of a rapid transit project comes from a source not even equipped to carry out implementation, such as the comprehensive transportation planning process. The recommendation of rapid transit is made as part of a long-range transportation plan, including suggested designation or formation of an agency to begin work. Often, questions of timing, technology (rail or bus), and locational details are addressed only in schematic form. The legislature acts on the strength of this general recommendation to enact legislation for "an Authority to plan, design, build, and operate a rapid transit system," usually leaving the question of financing unresolved, contingent on a successful application for federal funding, a successful bond referendum, and/or enactment of additional legislation.

The members of the transit authority very quickly perceive that its success will be judged by how quickly they get a system planned, financed, designed, and under way. They also intuitively comprehend that getting anything built at all will require broad-based political and public support, which, in turn, is much more easily achieved with a system that is big, bold, glamorous, fast, extensive, and, above all, which appears to serve as much of the affected area as possible from the day the system first opens. Since even a small start on one short line will in itself be a huge public works project, it is much easier to sell the full system if it appears to serve more people. It may be easier to sell a major urban area a $3 billion project than a $300 million project.

At this point the authority finds itself pulled by opposing forces: the local desire or political requirement for an extensive system and the demand of others, especially the senior governments being called on to finance much of the project, for a truncated, less costly undertaking. The senior government knows it cannot get enough money to fund all the system being planned and suspects that good transportation planning, economic analysis, and common sense would dictate a plan that begins small and develops over time.

The federal government, specifically the U.S. Department of Transportation's Urban Mass Transportation Administration (UMTA), was made the prime example of such senior government in the United States by the Urban Mass Transportation Act of 1964. To conserve scarce federal resources, UMTA has established the policy of funding only one minimum operable segment of new systems at a time and requires a major capital investment planning process that includes the determination of cost effectiveness through a detailed analysis of transportation alternatives.1

The dominance of financial influence on planning decisions and the different effect of alternative funding arrangements can be clearly identified from actual cases. Toronto and Baltimore began their rapid transit systems with funding sources that were constrained but required no referendum, and their first sections were the central portions of single lines. In contrast, Washington, San Francisco, and Atlanta all required bond authorization referenda, and all proposed multiple-line, total systems, originally scheduled for completion as a package so that all areas received a commitment for service on a defined schedule. Seattle and Houston, after initial failures at bond referenda, changed course and proceeded incrementally using available funding sources. With expanded availability of federal funding, coupled with the federal policy of starting with no more than one minimum operable segment, Miami, Buffalo, Portland (Oregon), and Santa Clara County (California) all moved forward with single lines. Minneapolis—St. Paul and Dallas, having aspirations far in excess of likely federal involvement, illustrate a possible resurgence of multiple-line system proposals.

ATTITUDINAL FACTORS

Decisions relating to the building of rapid transit, as well as the type of system, are heavily influenced by local attitudes and preconceived notions about the importance of transit improvements quite apart from the analytical presentations of the planning studies.2 All the larger cities of the United States had comprehensive transportation studies performed as part of the requirements of the 1956 Federal-Aid Highway Act, and most of these recommended a much more modest role for transit than has been subsequently proposed. Improvements in analytical techniques do not explain the differences; the differences relate to the value systems of the citizenry. Major concerns with environment, urban development patterns, and social issues have all surfaced since that time, and in response the evaluative processes and starting assumptions have shifted more to transit's favor.

Often the attitude is not necessarily pro-transit so much as it is antihighway or anti-automobile. San Francisco, Washington, Baltimore, Boston, Sacramento, and Portland are all cities that over time have experienced antifreeway movements that have helped promote the cause of transit. Concern for the environment was perhaps the factor uppermost in the minds of voters in the Denver area in 1975 when they approved the development (never carried out) of a system to cost more than $1 billion before being presented with details of the system's hardware, performance, or required time for development. Sometimes civic boosterism is a motivating factor, especially when two areas that have a tradition of rivalry consider transit development.

Executive interviews in Atlanta, Miami, Portland, and San Diego, conducted in 1989 after rail transit implementation, identified rapid transit as being perceived to bring cities an enhanced quality of life, an improved civic image, an assist to marketing and promotion, and a favorable impact on intraregional development and land-use decisions.3 The most cited reason for building rapid transit was the perceived need to move large numbers of people; some individuals in Miami admitted that the initial image of their rail system suffered due to low ridership, among other things. Perceptions in Atlanta, Portland, and San Diego were reportedly very positive, notably so in Portland where downtown retail activity and sales increased and public policy favoring development along the rail line with all sorts of supporting incentives was having the desired effect, even during a depressed economy.

For years the federal government has explicitly promoted the concept of carrying out transportation planning at the local level, with local planning officials responsible for the outcome. It is therefore inevitable, and perhaps even desirable, for each community to develop criteria that are responsive to its unique values and aspirations. The problem comes when these predispositions fly in the face of physical or economic reality. It makes no economic sense to build a $300 million rapid transit line to carry 5000 passengers/day no matter what one's aspirations, especially if financial assistance is being asked of some other level of government.

PHYSICAL FACTORS

Regardless of attitudes or institutional arrangements in a community, the size and physical relationships of activities and geography either lend themselves to the type of service that rapid transit provides or they do not. These physical factors are the primary determinants of the ultimate cost of constructing the system and of the number of riders over whom this cost can be distributed. No degree of rapid transit attractiveness can make up for ridership potential that is not there because of urban configuration.

There have been numerous efforts to measure city attributes in ways that will quickly identify those that can justify rapid transit. Table 11-1 lists several such indicators. Most are directly related to measures of potential passenger demand, and many could be accepted as valid for most cases. There are unquestionably minimum city and central business district (CBD) sizes and densities below which no form of rapid transit makes economic sense.

Criteria related to corridor flows, central-city density, or CBD size must be used with caution, however, since the definition of a corridor, what constitutes a CBD, and the boundaries of the central city vary among urban areas. The degree of travel dispersion likewise varies. There are inevitably exceptions to aggregate criteria.

One major factor often omitted in lists of indicators is city configuration. Figure 11-1 shows four representative city configurations, assumed for purposes of discussion to have equal population. Configuration B is a typical city with a CBD in the center and the urban area spread in a 360’ pattern around it. On average, only one-eighth of CBD-oriented travel will occur in any one 45° corridor. A rapid transit system serving such an area might require eight spokes. Examples are Washington and Denver.

TABLE **11-1**
Selected Rapid Transit Feasibility Criteria

Criterion	Desired or Minimum Threshold for System Development: Rail (desired)	Rail (minimum) or Bus	Busway (minimum)
Urban-area population	2,000,000	1,000,000	750,000
Central-city[a] population	700,000	500,000	400,000
Central-city[a] population density (people/mi^2)[b]	14,000	10,000	5000
CBD floor space (ft^2)[c]	50,000,000	25,000,000	20,000,000
CBD employment	100,000	70,000	50,000
Daily CBD destinations/mi^2[b]	300,000	150,000	100,000
Daily CBD destinations/corridor	70,000	40,000	30,000
Peak-hour cordon person movementsleaving the CBD (four quadrants)	75,000-100,000	50,000-70,000	35,000

[a] Central city refers to the effective central city, including the central city and contiguously developed areas of comparable density.

[b] Metric conversion: 1 mi = 1.6 km. Metric conversion: 1 ft = 30.5 cm.

Source: Adapted from Herbert S. Levinson, Crosby L. Adams, and William F. Hoey, *Bus Use of Highways: Planning and Design Guidelines*, NCHRP Report 155 (Washington, D.C.: Transportation Research Board, 1975), p. 26.

Configuration C would require only five spokes to provide the same effective coverage, with each spoke serving a higher percentage of all travel. Examples are Toronto and Chicago. Configuration D can be served with only two spokes, each carrying heavy volumes. Examples are Honolulu and Caracas, Venezuela.

The most difficult configuration of cities is shown in configuration A. An example is the Twin Cities of Minneapolis and St. Paul. A line linking the two CBDs in such a configuration may be singularly effective, but 14 other spokes are required to provide full coverage.

Clearly, the rapid transit systems for each area shown decrease in price from configurations A to D. Moreover, the level of service goes up, since requirements for passenger transfers go down. Finally, within the assumption of equal population, the number of passengers per line goes up. Highway capacity deficiency and auto congestion problems, measures of rapid transit need and viability, also increase as one goes from A to D, since all travel is concentrated into fewer corridors. Aggregate criteria that do not recognize the configuration factor will encounter many exceptions.

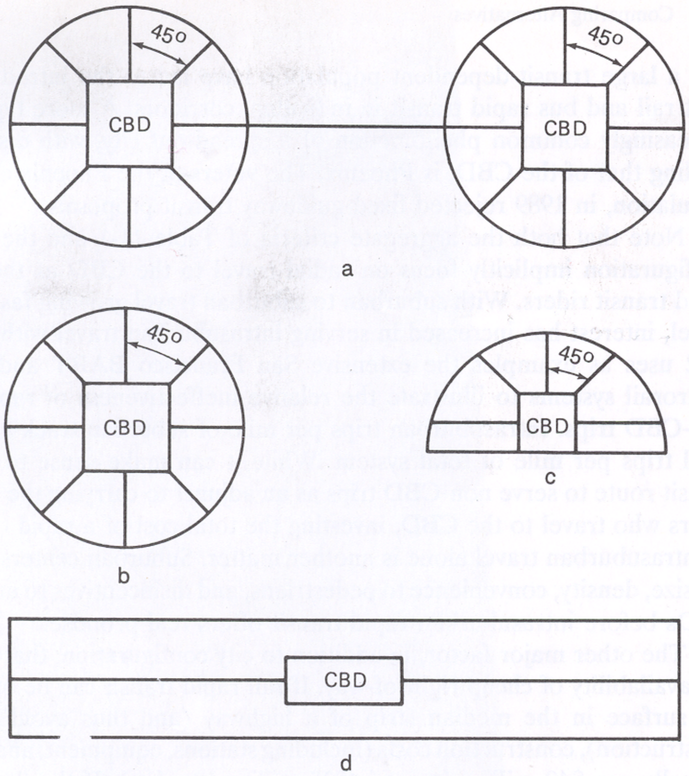


Figure 11-1 *Representative city configurations (equal population). [Source: Adapted from Thomas B. Deen, Walter M. Kulash, and Stephen E. Baker, "Critical Decisions in the Rapid Transit Planning Process," in* Transit Planning, *Transportation Research Record 559 (Washington, D.C.: Transportation Research Board, 1976), pp. 33-43.*

Configuration is a major reason why Honolulu, even though projected to have less than 1 million persons in the standard metropolitan area, can be in project planning for fully grade separated fixed-guideway rapid transit. Thanks to configuration D, their system can serve the city with a single through line and is projected to carry daily volumes of over 80,000 passengers on each of the two approaches to the city center. In contrast, the configuration A cities of Minneapolis and St. Paul, with 2.3 million population, are in the initial steps of a 20-year plan for lower-volume semirapid transit, which attempts to serve many but not all the multitude of corridors.

The worst situation for rapid transit is when individual lower-density suburban centers approach or exceed the size of employment in the CBD, creating a proliferation of travel patterns and corridors exceedingly difficult to serve effectively. The classic example has been Los Angeles, where now sheer size (the second-largest city of the United States, with the seventh largest CBD), accompanying congestion and pollution, and a large transit-dependent population have led to the introduction of heavy and light rail and bus rapid transit in individual corridors. A more typical example of the increasingly common phenomenon of a spread-out city, with dispersed employment rivaling that of the CBD, is Phoenix. The voters of the Phoenix area, with 2.0 million population, in 1989 rejected fixed-guideway transit proposals.

Note that both the aggregate criteria of Table 11-1 and the examination of city configuration implicitly focus on radial travel to the CBD as the primary source of rapid transit riders. With suburban to suburban travel growing faster than other urban travel, interest has increased in serving intrasuburban travel with rapid transit. Table 11-2 uses as examples the extensive San Francisco BART and Washington, D.C., Metrorail systems to illustrate the relative ineffectiveness of rapid transit in serving non-CBD trips. Intrasuburban trips per mile of suburban track are only a fraction of total trips per mile of total system. While it can make sense to align a radial rapid transit route to serve non- CBD trips as an adjunct to carrying the 80% or so of system riders who travel to the CBD, investing the total cost of a rapid transit line in service to intrasuburban travel alone is another matter Suburban centers will have to achieve the size, density, convenience to pedestrians, and disincentives to auto use of center-city CBDs before intrasuburban rapid transit offers real promise.

The other major factor, in addition to city configuration, that causes exceptions is the availability of cheap right-of-way. If rail rapid transit can be built, for example, on the surface in the median strip of a highway (and thus avoid subway or elevated construction), construction costs (including stations, equipment, and right-of-way) might typically run $40 million/rte.-mi ($25 million/rte.-km). If the line is required to run underground, however, costs for subway construction might be 6 times this amount. Cleveland, Ohio, built their modest but effective rail rapid transit system even though patronage was only 4000 persons/h on one of their lines. Building rail rapid transit for such a low patronage made sense only because of the very low cost of the system when built in 1955, which in 1990 dollars would be $23 million/rte.-mi. The low cost was possible only because of the availability of an inexpensive right-of-way along existing railroad lines that required no tunneling and very little elevated construction.

Figure 11-2 shows the importance of construction costs in determining the total cost of transporting people. It should be noted that the total capital, operating, and maintenance cost of transporting people in automobiles or on the local buses of major cities is in the range of 25 to 50 (16 to 31) cents/passenger-mi (passenger-km) overall, or 25 to 75 (16 to 47) cents/passenger-mi (passenger-km) if the upper end of the range is keyed to the incremental cost of new facilities to accommodate commuter travel by auto. From Fig. 11-2 it can be seen that 20,000 passengers/day might be all that is required to maintain a 50 cent/passenger-mi cost if a rapid transit line can be built for $10 million/mi, whereas if capital costs are $100 million/mi, patronage must be 100,000/day to achieve a 75 cent/passenger-mi cost.

The all-important issue of physical factors boils down to the bottom-line question of what it is going to cost per passenger-mile to transport people via rapid transit. If this cost exceeds the cost of other options by significant amounts, then any justification offered in terms of overall community benefits must be examined more critically before

TABLE 11-2
Crosstown and Intra/Intersuburban Travel via Rapid Transit

San Francisco Bay Area Rapid Transit District: April 26,1989 BART Ridershipa

	Weekday Trips		Stations		Length of Track			
	Number	Percent	Number	Percent	Miles	Percent	Trips per Station	Trips per Milec
Total system	216,900	100	34	100	71	100	6400	3100
System excepting	47,800	22	27	79	67	94	1800	700
Intra-and inters-								
Uburts only	19,800	9	18	53	41	58	1100	500

Washington Metropolitan Area Transit Authority: 1990 Metrorail passenger Surveyb

	Weekday Trips		Stations		Length of Track			
	Number	Percent	Number	Percent	Miles	Percent	Trips per Station	Trips per Milec
Total system	519,000	100	61	100	70	100	8500	7400
System excepting	77,800	15	43	70	56	80	1800	1400
Intra-and inters-								
Uburts only	35,300	7	28	46	39	56	1300	900

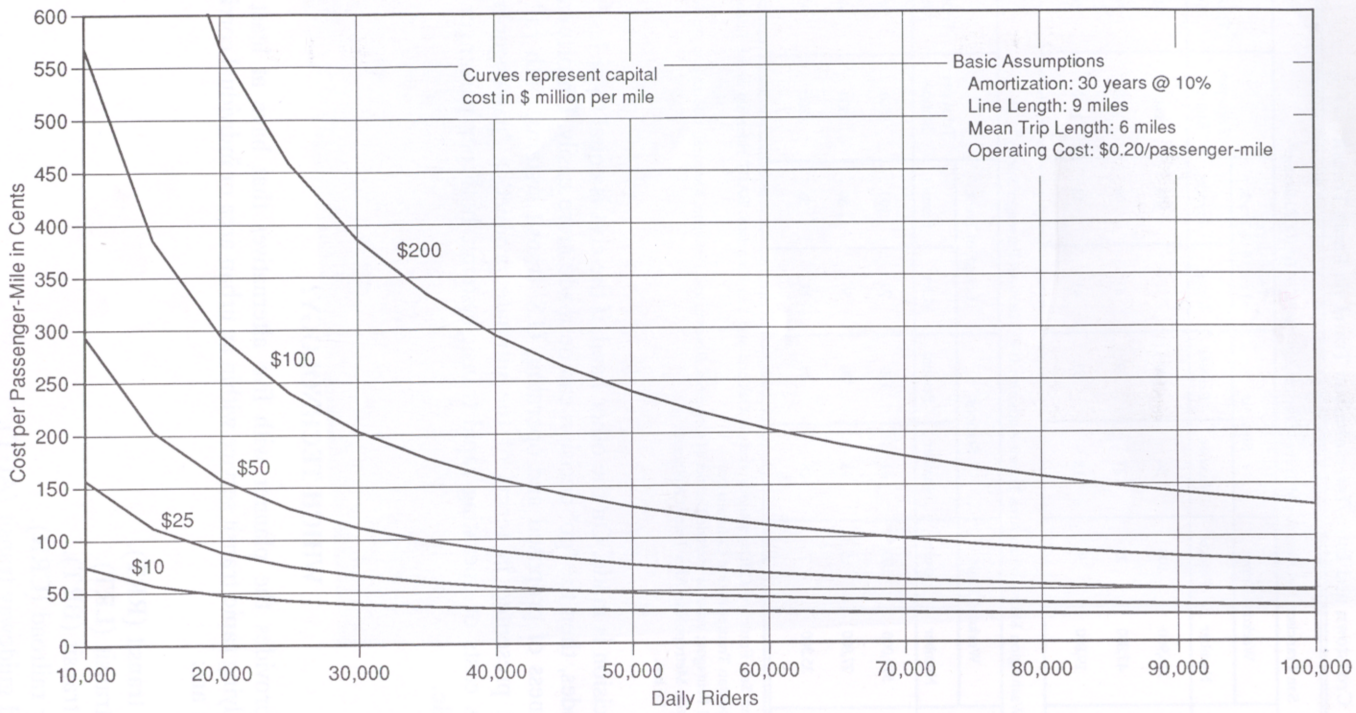
aCBD includes Oakland and San Francisco CBDs; suburts exclude Oakland and San Francisco. BART ridership is pre-Loma Prieta earthquake. Source: Metropolition Transportation Commission.
BCBD includes Rosslyn and Pentagon: suburbs exclude District of Columbia, Rosslyn and Pentagon. Metrorail ridership is pre-wheaton extension. Source: Washington Metropolitan Area Transit Authority.
CMetric convesion: 1 mi=1.6 Km.

An affirmative decision is made. On the other hand, if the cost is equal to or less than other existing modes. Then the “go” decision can be made more easily. Unfortunately, the cost effectivence of proposed and operating U.S. transit systems, both rail and bus, is often not presented in terms of the ultimate product, a “passenger-mile”. Table 11-3 shows costs of operating rapid transit systems, both per passenger and per passenger-mile.

WHICH TECHNOLOGY?

Technology provides the planner with five alternatives that have at least the potential for supplying rapid transit service within an urban area or individual corridor.
These five modes are:

- Rail rapid transit (RRT)
- Light rail transit (LRT)
- Bus rapid transit (BRT)
- Commuter railroad (CRR)
- Automated guideway transit (AGT)



* Metric conversion: 1 mi = 1.6 km.

Figure 11-2 *Cost per passenger-mile versus daily patronage. [Source: Compiled by William G. Allen, Jr., for the Transportation Research Board, adapted from report by Alan M. Voorhees & Associates, Inc.,* A Long Range View of Transit in Nashville *(McLean, Va.: Alan M. Voorhees & Associates, Inc., September 1970, rev. September 1971).]*

TABLE 11-3

Costs for Several North American Rapid Transit Systems

Item	Rail Rapid Transit				Light Rail Transit				Busway[a]		Automated Guideway Transit		
	Atlanta	Balt-more	Miami	Wash-ington	Buffalo	Pitts-burgh	port-land	San diego	LA. monte	Pitts-burgh	Detroit DPM	Miami DPM	Van-couver
Year of primary data	1987	1987b	1988	1986	1987	1989	1989	1988	1983-86	1987	1988	1988	1987
Annual patronage (mi llions)	53.7	119	10A	116.0	8.1	9.0	6A	8A	5.7	12 2	3.2	3.2	18.0
Daily patronage (thousands)	184.5	42.6	35.4	411.6	29.2	30.6	19.7	27.0	22C	47. 0	113	10.8	58.0
Capital costs (millions of 1988 $)	2720	1289	1341	7968	722	622	266	176	144	216	215	175	640
Annual capital costs (millions of 1988 $)	278.1	131.8	137.1	814.8	73.8	63.6	27.2	18.0	8.1d	22.1	22.0	17.9	65.4
Annual operating costs (millions of 1988 $)	403	21.7	375	1999	11.6	8.1	5.8	72	109	6.7	109	4.6	19.1
Total annual costs (millions of 1988 $)	318.4	1535	174.6	1014.7	85.4	71.7	33.0	25.2	19.0	28.8	329	225	84.5
Cost per passenger-trip (1988 $)	5.93	12.90	16.79	8.75	1055	7.97	5.16	3.00	334	236	1028	7.03	4.70
Average trip length ((mi)e	5.3	3.6	7.8	6.2	3.6	6.1	6.1	9.5	7.1f	45	1.5f	1.0f	7.2f
Cost per passenger-mi ($)	1.12	3.58	2.15	1.41	2.93	131	0.85	032	0.47	0.52	6.85	7.03	0.65

Metric conversion: 1 mi = 1.6 km.

aIncludes the cost of purchasing and operating buses (busway portion of affected routes only).

bData does not include Owings Mills extension.

cBus passengers only (does not include carpool/vanpool passengers).

dComputed by allocating *55%* of cost to bus operation (in proportion to bus ridership vs. total HOV facility person volume).

eRevenue (linked trip) guideway trip length.

fEstimated by the authors as a function of line length.

Sources: Compiled by William G. Allen, Jr., for the Transportation Research Board from various sources, including: Don H. Pickrell, *Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs* (Washington, D.C.: Urban Mass Transportation Administration, 1989); A. D. Biehler, "Exclusive Busways Versus Light Rail Transit: A Comparison of New Fixed-Guideway Systems, in *Light Rail Transit: New System Successes at Affordable Prices,* Special Report 221 (Washington, D.C.: Transportation Research Board, 1989), pp. 89-97; Texas Transportation Institute, *Transit System Comparison Study–Comparative City Data Base,* Rail Research Project, prepared for the Metropolitan Transit Authority of Harris County (Houston, Tex.: Texas Transportation Institute, August 1989); Crain & Associates, Inc., *The Martin Luther King, Jr., East Busway in Pittsburgh, PA,* prepared for UMTA (Menlo Park, Calif.: Crain & Associates, October 1987); N. D. Lea & Associates, Inc., *Assessment of the San Diego Light Rail System* (Washington, D.C.: N. D. Lea & Associates, November 1983); Samuel L. Zimmerman, "UMTA and Major Investments: Evaluation Process and Results,. in *Transit Administration and Planning Research,* Transportation Research Record 1209 (Washington, D.C.: Transportation Research Board, 1989), pp. 32-36; H. S. Levinson and *others, Bus Use of Highways: State of the Art,* NCHRP Report 143 (Washington, D.C.: Highway Research Board, 1973).

Modal definitions are provided in Chap. 4. Note that for this discussion BRT will be taken to encompass any system utilizing buses operating, for at least the major portion of their routes, on exclusive or reserved paved rights-of-way (busway or transitway), permitting high-speed operation, including priority lanes on limited access roads. The reserved pavement may be shared with other high-occupancy vehicles (HOVs) as long as degradation of bus operations does not result.

Commuter railroad operation is a special case in the selection of technology, since the availability of a well-constructed railroad line appropriately situated is a prerequisite. Most CRR operations, such as those of New York, Chicago, Philadelphia, San Francisco, and Boston, perform their vital transportation role with track and terminal facilities built by the private railroad companies long before changing circumstances removed the profit from railroad passenger service. There have been many studies of the potential for new CRR, but the economic trade-offs almost always look unfavorable, except for the occasional upgrading and expansion of existing service.

Justification of completely new CRR service is likely only in those few metropolitan areas where (1) railroad track is already in good condition, (2) the tracks penetrate deep into the CBD and good distribution is available from the central terminal to other destinations, (3) significant residential population can be served by the outlying track locations, and (4) the commuting distances involved are long, typically 10 to 50 mi (16 to 80 km) for most passengers. Toronto's GO Transit is the preeminent example of a new system.

Within the emerging family of technologies classified as automated guideway transit (AGT), two major subgroups have achieved operational status. One group, typified by people-mover systems of modest speed, serves the relatively short trip movements found in major activity centers, including a few downtowns and campuses and a relatively large number of major airports. The other group consists of higher-speed line-haul applications and represents the type of AGT of primary interest as a rapid transit option. These line-haul applications hold promise but still exhibit "teething problems." The only installations presently approaching metropolitan scale are those in Lille, France (VAL), and Vancouver, B.C. (SkyTrain). As a rapid transit technology, this form of AGT is close to RRT, but can employ vehicles that are still small compared to RRT or LRT, structures that are lighter, and service envelopes that require less horizontal and vertical clearance. All AGT must be fully grade separated. (See Chap. 24 for a detailed discussion of AGT systems.)

This leaves most cities with two sets of technology choices, as a practical matter, within the widening spectrum of rapid transit options. One set of choices is bounded by heavy and light rail transit, with line-haul AGT as a promising variation, and the other set is comprised of BRT and the various opportunities for BRT integration with HOV facilities. In area after area, the choice is agonizing, being made only after years of debate, delays, and great frustration. The record suggests that in some cases the choice gets confused and is used by those who prefer no system to delay the process altogether. In many cases the arguments are waged at a superficial and emotional level and often overlook the fact that the choice of technology is only one of a number of choices necessary, some of which can affect costs and service more than the technology issue.

Several studies have been made that try to compare the relative costs of the systems (particularly RRT and BRT), with widely varying results. For example, Miller and others[4] found that RRT was almost always cheaper, whereas the Institute for Defense Analyses[5] found that BRT is always cheaper. Deen and James[6] found that either could be cheaper, depending on the volume to be carried and on the extent of the subway segments required. Subsequent studies continue to cover the spectrum of findings.[7,8] The reasons for such variance among responsible investigators are many, but there are two that dominate the confusion.

1. A failure to recognize the huge differences in costs associated with alternative vertical alignment configurations.

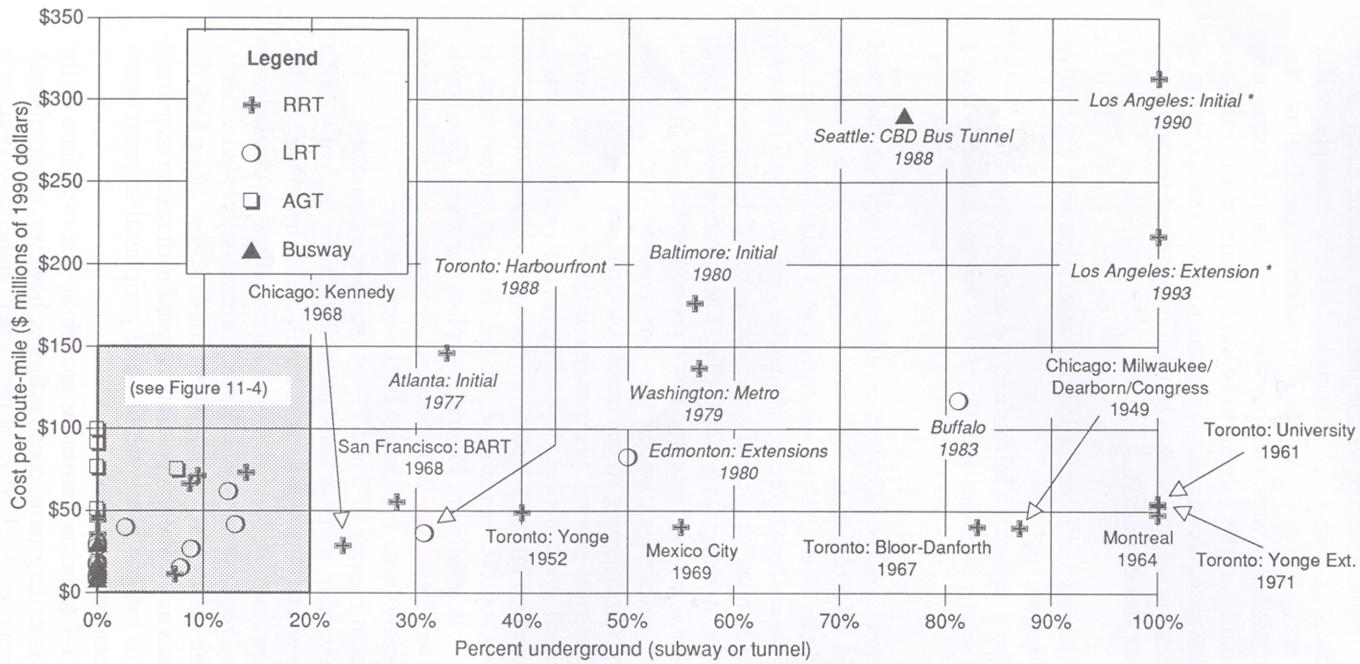
2. A failure to recognize the complexities intrinsic to the decision to select subway versus elevated versus surface on exclusive right-of-way versus surface in mixed or restricted traffic.

Even including all components unaffected by vertical alignment (such as power and signal systems, yards and shops, and rolling stock), underground construction costs 2 to 3 times that of elevated, and elevated construction costs 2 to 3 times that of surface construction. Finally, surface systems (or segments) themselves can vary by a factor of 2 to 3, depending on whether they must be located on an exclusive right-of-way or can be located on streets mixed with or alongside other traffic. These ratios tend to hold true for all fixed-guideway technologies and become more pronounced (2 to 5) in the case of BRT. Their sheer magnitude guarantees that any analysis that does not explicitly account for them is probably going to get unreliable answers.

Figures 11-3 and 11-4 illustrate several phenomena including the very large differences in cost of rapid transit construction, depending on the extent of surface, elevated, or underground alignment. Figure 11-3 plots the per-mile costs of RRT, LRT, AGT, and BRT as a function of the percentage of the line or system that is underground, the dominant cost determinant. Figure 11-4 plots the same data points over time for those examples with less than 20% of their alignment underground so that they can be seen more clearly (note the change in the cost scale).

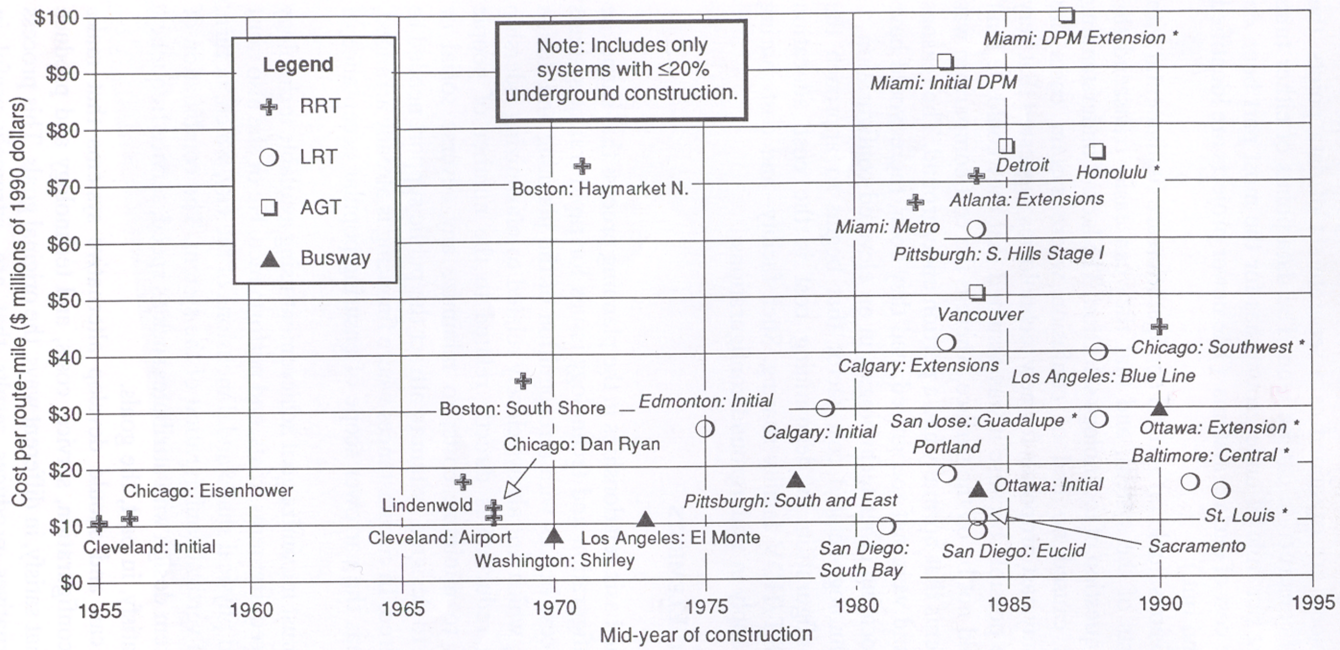
One pattern that stands out in Figures 11-3 and 11-4 is the increase in construction cost over time, even after conversion to 1990 constant dollars, with the early 1970s being a watershed between lower and higher cost systems. It can be hypothesized that the higher costs of the newer projects reflect additional expenditures associated with environmental impact mitigation requirements, handicapped accessibility requirements, and increased pressure from the citizenry for nonintrusive construction, along with the provision of more amenities such as escalators, possibly coupled with taking advantage of expanded funding sources to include more niceties and peripheral improvements than would previously have been contemplated.

What appears in Figure 11-4 to be an enormous growth in cost over time in the case of systems with 20% or less underground construction is, however, predominantly the result of the type of alignment involved. Most of the newer, higher cost systems in Fig. 11-4, specifically the AGT systems and Miami RRT, have large components of



* Projected (year is mid-year of cost data).
Note: Costs include right-of-way and equipment. Systems 1975 or newer shown in *italics*.

Figure 11-3 *Fixed-guideway system costs versus percentage underground. [Source: Compiled by William G. Allen, Jr., for the Transportation Research Board; adapted from various sources, including: J. Hayden Boyd, Norman J. Asher, and Elliot S. Wetzler,* Evaluation of Rail Rapid Transit and Express Bus Service in the Urban Commuter Market *(Arlington, Va.: Institute for Defense Analysis, October 1973). Don H. Pickrell,* Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs *(Washington, D.C.: Urban Mass Transportation Administration, 1989). Parsons Brinckerhoff Quade & Douglas, Inc., Company files. J. W. Schumann, "What's New in North American Light Rail Transit Projects?" in* Light Rail Transit: New System Successes at Affordable Prices, *Special Report 221 (Washington, D.C. Transportation Research Board, 1989), pp. 8-42. Arlee T. Reno and Ronald H. Bixby,* Characteristics of Urban Transportation Systems, *prepared for UMTA (Washington, D.C.: System Design Concepts, Inc., October 1985).]*



* Projected (year is mid-year of cost data).
Note: Costs include right-of-way and equipment. Systems 1975 or newer shown in *italics*.

Figure 11-4 *Fixed-guideway system costs versus mid-year of construction. [Source: Compiled by William G. Allen, Jr., for the Transportation Research Board; adapted from various sources, including: J. Hayden Boyd, Norman J. Asher, and Elliot S. Wetzler,* Evaluation of Rail Rapid Transit and Express Bus Service in the Urban Commuter Market *(Arlington, Va.: Institute for Defense Analysis, October 1973). Don H. Pickrell,* Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs *(Washington, D.C.: Urban Mass Transportation Administration, 1989). Parsons Brinckerhoff Quade & Douglas, Inc., Company files. J. W. Schumann, "What's New in North American Light Rail Transit Projects?" in* Light Rail Transit: New System Successes at Affordable Prices, *Special Report 221 (Washington, D.C. Transportation Research Board, 1989), pp. 8-42. Arlee T. Reno and Ronald H. Bixby,* Characteristics of Urban Transportation Systems, *prepared for UMTA (Washington, D.C.: System Design Concepts, Inc., October 1985).]*

elevated construction. When Figs. 11-3 and 11-4 are looked at together, and either the pre-1975 or the newer projects are examined as a separate set of data points, the importance of underground construction can be seen. The data points of either time period indicate that the cost per mile of underground has for the most part been on the order of 3 to 6 times the cost of surface systems. (The newer projects are identified in italics to make them stand out.)

It is fair to say that decisions made on vertical configuration are fundamental with respect to the ultimate costs of the system, and that they can easily transcend the related, but often separate, question of technology selection. The lack of understanding of these relationships has caused no end of confusion where system costs are compared. For example, many past proposals for new technologies suggested that very large cost savings would be possible because it was assumed that they could be built elevated anywhere they could not be on the surface, whereas the cost comparison was with conventional RRT systems that normally had a portion underground. The reasons for placing RRT underground were not recognized; had they been, there would have been less optimism about locating other technologies in an elevated configuration.

Probably the only technology-related cost factor that begins to approach the importance of vertical configuration in determining cost is the cost allocation opportunity afforded by BRT/HOV facility sharing. Such facility- and cost-sharing opportunities would rarely apply in underground configurations.

RELATIONSHIP OF PLANNING ELEMENTS

Figure 11-5 depicts some basic relationships in the planning process that shape the decision on the vertical configuration and technology issues for rapid transit systems or individual lines. The process begins with a recognition of the planning and design goals: to maximize benefits, which are always closely related to maximizing ridership (for example, air pollution reduction is directly related to the number of people attracted from their cars); to minimize costs; to minimize any adverse social or environmental impacts; and to design a system to attract the public support needed to generate the financing required. In circumstances where financing is already arranged, the goal of public support has the narrower scope of ensuring popular acceptance of actions taken.

The designer—planner must maximize goal achievement using available technology with its constraints of space requirements, costs, and performance. He or she also must allow for the topography and physical shape and dimensions of the city, which, in turn, influence the horizontal and vertical configuration of the system. The combination of the elements produces a system design with attributes such as speed, service frequency, capacity, and costs, which satisfy, in part, the goals.

The designer—planner can and should develop alternative systems that make different trade-offs among configuration, service, costs, and technology and produce different system attributes that satisfy, in different ways, the original goals. This process of trying and testing alternatives produces results that are extremely useful in improving many aspects of system design, but are never entirely conclusive or compelling with respect to some of the most major issues, since no system will fully achieve all the goals. In the end, the choices between the realistic alternatives available must be resolved through political compromises achieved by the many varied interests involved. The main point from Fig. 11-5 is that the attributes of the selected system are influenced by goals and configuration, as well as technology constraints.

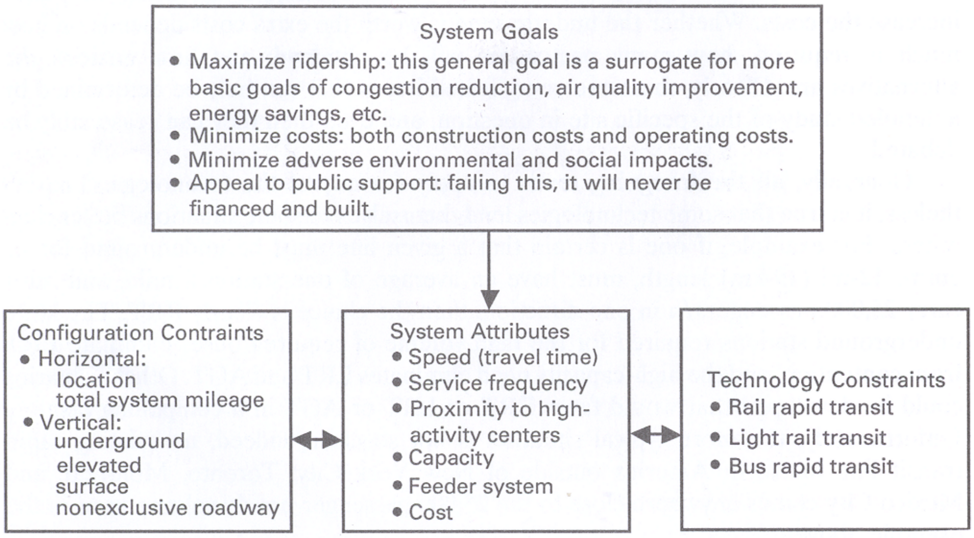


Figure 11-5 *Relationship between elements influencing system planning.*

One of the fundamental trade-offs that must be made in system planning is among:

- The system's total mileage.
- The ease of access the system affords to the high-activity centers of the city.
- The scheduled speed of the system.
- The selection of vertical configuration.

One of the first difficulties faced by the transit planner in developing alternative system plans for evaluation is that no system can provide much of a boost to service unless it can provide service within a convenient walking distance of the traveler's ultimate destination or origin. Secondary feeder services can often be used at one end of the trip (thus inducing one mode transfer), but rarely can the traveler be induced to make two mode transfers. Therefore, there is a high priority on locating stations very close to the centers of the highest-density areas of the city, the very locations where land costs are at a premium, where existing rights-of-way are least likely to exist, where elevated segments are most likely to meet strong resistance, where the demolition associated with any grade separated construction on the surface is difficult, disruptive, and expensive, and where the traffic and pedestrian conflicts of operation at grade are the toughest to resolve. Because of the cost multiples involved in going underground, it is safe to say that the choice of underground would almost never be made were it not for these factors. In many instances, if underground is not practical, then the proposed transit improvements will not be made.

Planners can reach more activities within a given rapid transit mileage allotment through the use of more underground. In so doing they increase potential ridership and the benefits to be derived from the system. Unfortunately, by so doing they also increase the costs. Whether the underground is worth the extra costs depends on how much is required, how many passengers will be obtained, and how noxious the alternatives are. Clearly, these are complicated issues that can only be determined by a detailed study of the specific site in question, and even then they can reasonably be debated.

Generally, all the foregoing tends to apply for any of the technologies; nevertheless, it is true that some technologies lend themselves to some situations better than others. For example, if one is certain that a given line must be underground for its entire 12-mi (19-km) length, must have an average of one station a mile, and must carry 25,000 passengers/h in one direction, then the choice is clearly RRT. The large underground stations required for the high volume of required buses eliminate BRT from contention, and the high-capacity need eliminates LRT and AGT. Other scenarios could be developed that would favor BRT or LRT or AGT in a compelling fashion. Unfortunately, the more typical situation is not so clear; indeed, no existing rapid transit line in North America outside of New York City, Toronto, Montreal, and Mexico City comes anywhere close to the 25,000 passenger hourly volume used in the example above.

Table 11-4 shows in tabular form some of the more frequently encountered relationships involved in translating system goals into design objectives and, in turn, into design methods and technology attributes. For example, to meet the goal of minimizing construction cost, the designer might choose the objective of maximizing the use of shared facilities, seeking to run on HOV lanes and transitways open to carpools and vanpools. In this case, BRT would be the favored technology, being capable of operation in all types of HOV configurations. LRT would be second choice, being appropriate for limited running in arterial HOV lanes only, and the last choice would be RRT and AGT with their requirement for exclusive guideways.

RAIL SYSTEMS VERSUS BUS SYSTEMS

While the choice between RRT, LRT, and AGT is often difficult, the really intense controversies seem to be generated in making the choice between these rail fixed- guideway systems and bus systems. Understanding these controversies requires a recognition that very large economic interests are differentially affected by the final choice, with highway—automobile interest groups tending to favor bus systems, while interest groups aligned with the providers of rail equipment and related industry tend to support rail systems.

Perhaps the greatest factor working against the use of buses is related to the public's attitude. Existing local bus transit, particularly in the United States, has a

TABLE 11-4
Some Relationships Between Design Goals and Technology Attributes

Goal/Design Objective	Design Method	Technology Suitability Rank RRT	AGT	LRT	BRT
Maximize ridership/ Locate stations within easy walk of many major centers	Locate system underground to allow unobtrusive/ nondisruptive high-capacit entry into high-density areas	1	2	2	3
	Locate system in surface streets/malls of major centers. with first-floor-level stops	2	2	1	1
	Use high line mileage and many stations systemwide	1	1	1	1
Provide high-frequen-cy service	Use short trains or single-vehicle tranis with short headways	3	1	2	1
Maximize scheduled Speed	Provide grade separation and high-speed alignment for entire system	1	2	3	4
	Provide skip-stop and express service	2	2	2	1
Reorganize transit service systemwide	Remove radial service; provide focus to reorient bus routes into community/ cross-town operation.	1	2	3	4
Maximize development impact/ Stress accessibility and permanence	Use fixed-guideway with substantial stations central to areas of potential development/redevelopment	1	2	3	4
Minimize construction cost/ Use of existing ROW to avoid	Use freeway mediansm, railroad/power-line right-of-way though these may be distant under-from activity centers	1	1	1	1
ground/elevated construction	In lower-density areas, let system run on streets/ highways mixed with other traffic	3	3	2	1
Maximize use of shared Facilities	Run on HOV lanes and other facilities open to carpools/vanpools	2	2	2	1
Reduce total construction Required	Reduce system mileage, number of stations	1	1	1	1
	Use shorter, simpler stations, low platforms, etc	2	2	1	1
	Use smaller horizontal and vertical clearances, lighter structures	2	1	2	2
Reduce system complexity	Eliminate power distribution an control systems	3	3	2	1
Minimize operating cost/ Reduce operating personnel	Use long trains to reduce personnel/ passenger ration	1	2	2	3
	Use more complex systems Affording greater automation	2	1	3	4
	Use short trains in off-peak	3	1	2	1
Reduce maintenance personnel	Use simpler systems with less Electronics and hardware	3	4	2	1
Maximize public support/ Provide service to widest possible area	Use low cost/mile systems, maximum use of at-grade, nonexclusive right-of-way	4	3	2	1
Fit predispositions of public	Use rail/fixed-guideway systems; Avoid bus systems	1	1	1	2

tarnished image with most urbanites, and proposals for bus rapid transit tend to be marked with the stigma. New rail/fixed-guideway transit systems, on the other hand, tend to have a very favorable image in the public mind. Thus, the agency proposing a bus system, particularly one requiring a large capital investment and voter approval, must make an uncommonly convincing case. Transit authorities sense this public sentiment and, partly as a result, have rarely gone to a bond referendum to build bus rapid transit with significant busway mileage. The Ottawa and Pittsburgh busways and the Los Angeles, Northern Virginia, and initial Houston bus/HOV facilities were all built with monies available without recourse to bond referenda. The successful 1988 Houston bond referendum, however, did cover additional bus/HOV facilities (transitways) in conjunction with a fixed-guideway component and highway improvements.

Institutional arrangements also tend to conspire against buses. The operator of the existing bus system may be a different agency than the one charged with rapid transit development, and the agency that would build busway/HOV facilities may be different yet. When control of the construction or the service that would be operated lies with others, the self-interest of transit development agencies and even their consultants has been known to weaken their interest in proposals to build busways, bus stations, and other such facilities.

Aside from attitudinal and institutional factors, inherent physical features distinguish the performance and cost characteristics of bus and rail/fixed-guideway systems. Achieving comparison of these features in such a way as to receive broad agreement is elusive; arguments about the relative efficiency of the two modes continue unabated. Both bus and rail systems have advocates that present their arguments in superficial terms that tend to obscure the real differences, which are already sufficiently complex. It is useful to examine some of the various claims as a way of highlighting the real differences between systems.

Bus advocates claim that:

1. *Buses are more flexible and can offer no-transfer service in response to diffuse trip patterns.* There is little doubt that buses have advantages over rail in the provision of direct service: buses are operated as single units, can be dispatched along individual routes set up for different travel markets, and can leave bus rapid transit facilities to access off-line sites. Nevertheless, direct bus service has its limits. No-transfer rides between many points can be provided only by sacrificing service frequency. An analysis for the Los Angeles area showed that providing for direct service between all potential bus collection areas would result in an average of two bus trips/day/route, clearly unacceptable.

2. *Buses can provide higher speeds than rail when used on a busway or HOV lane, since they can provide nonstop service.* This tends to be true in those cases where patronage is sufficient to support nonstop service. Buses can travel at nonstop speeds of 40 to 50 mi/h (64 to 80 km/h) on an urban busway. If stops are introduced to serve more origins and destinations, scheduled speeds may be somewhat lower than for rail transit with equivalent stops, owing to acceleration limitations. RRT systems run at scheduled speeds (including stops)

of 25 to 45 mi/h, depending on station spacing. LRT, as presently operated in the United States and Canada, operates at scheduled speeds of 10 to 21 mi/h.

3. *Buses are cheaper than rail, which is altogether too expensive.* The real cost issue between systems is not whether the use of buses on existing streets and highways is cheaper—it probably is—but whether comparable service free of traffic delays and congestion can be provided at lower cost. Buses using specially constructed busways may or may not be cheaper, depending primarily on passenger volume and whether the transit route must operate partially or wholly in subway. Costs of busway construction, including right-of-way (land) and vehicles, and excluding the one example involving a trolleybus subway, have ranged from $8 to $30 million/mi ($5 to $19 million/km), as illustrated in Fig. 11-4. The cost range for those RRT and LRT systems that are almost entirely on the surface starts at the same point but extends about 50% higher.

4. *If buses are given prior treatment, then buses can provide high-level service at much lower cost than rail.* Taking existing freeway lanes away from general traffic has proved impractical or politically infeasible in most instances. When new lanes can be built for HOVs including buses, a high level of service does become quite economical, the cost of the new lanes being spread across both carpools/vanpools and buses. Another cost-saving potential for buses in rapid transit service is that they have the flexibility to use any combination of running on busways, lanes reserved for buses or for all HOVs, freeways in mixed traffic, and/or streets in mixed traffic, so the more expensive options need only be used for those portions of a route where they are critical to bypass congestion and bring service close to high-activity centers.

Rail advocates claim that:

1. *Rail systems are more attractive to prospective users and thus can achieve a higher shift from auto to transit use.* Rail rapid transit, and *new* rail rapid transit in particular, is obviously more attractive than ordinary slow local bus service. However, most travel choice investigations have identified no special attractiveness for rail when bus service is equivalent in time, cost, and convenience. A few have shown a modest, unexplained preference for rail. This preference, if it exists, may be less a function of rail transit "sex appeal" than features often (but not uniquely) associated with rail transit, such as the service reliability afforded by separate rights-of-way, readily recognizable and weather-protected stops, off-vehicle fare collection, simple and easy-to-remember routings, and good service frequency.

.2. *Rail systems have more capacity.* This is true for RRT, but in a vast majority of cases, capacity is irrelevant. Many existing and proposed rail systems have peak loads that are well within the capacity range of bus systems. Present maximum load-point volumes on North American RRT lines exclusive of New York City, Toronto, Montreal, and Mexico City are in the range of 3000 to 15,000 passengers/h/track, and L-RT maximum load-point volumes are in the range

of 1000 to 10,000 passengers/h/track. RRT systems can be designed to carry 30,000 passengers/h/track and more; bus systems can carry a similar number per lane *as long as the buses do not stop on the roadway*. If passenger pickup
along the way is required, then the bus lane is limited to 8000 or so passengers/h, unless multilane, multiberth stations are provided. Such bus stations require more space than rail stations, and the space may not be available.

3. Rail systems are more energy efficient and do not cause as much air pollution. Superior energy efficiency may or may not be an attribute of a rail system, depending largely on the average occupancy of the vehicles. Research has shown, for example, that buses in large cities can be at least as energy efficient as RRT.9 Rail systems are less polluting in those instances where electrical power generation does not involve emissions, as in the case of hydroelectric or solar generation. Even if the power generation is polluting, the emissions problem at the site of the power plant may be less acute than in the city.

4. Rail systems have lower operating costs than bus systems. This may be true on systems not saddled with labor rules requiring superfluous personnel, at least as long as passenger volume is large enough to take advantage of the multiple-car per operator capacity of most rail systems. However, the need for skilled electronic maintenance personnel, station attendants, and in some cases special police, takes away from the staff cost savings once projected for automated systems. Rail systems, unlike many busways, are almost always restricted to one agency, limiting opportunity to foster service competition.

Representations about rail system attractiveness and lack of pollutant emissions are examples of arguments that obscure more fundamental underlying issues. Overall door-to- door travel time and convenience are of such importance to the prospective transit user that any special technology attractiveness that may exist is assuredly secondary to route and station location, service frequency and connectivity, and avoidance of congestion. Facility location and service requirements may in turn determine which affordable technology will work best. Likewise, the pollution issue may be overshadowed to the extent that both bus or rail with reasonable patronage cause relatively little pollution per passenger-mile compared to autos (assuming that bus emissions are, as presently mandated, brought more in line with auto emissions). The alternative providing superior service generally produces the most riders and the greatest diversion from autos, in turn resulting in the least pollution.

Flexibility is a broader concern than suggested by the directness of service question alone. The ability to adjust routings in response to changed travel patterns is another issue. There is little doubt that bus routes can be more easily changed than rail routes. Yet, if busways are built, those bus-route segments that use them are as fixed as a railway. Moreover, routing flexibility can be a disadvantage if one purpose of building a transit system is to encourage denser land-development patterns. Not to be overlooked is the ability of a radial rail system (or other technology similarly operated) to foster restructuring of the remaining bus service into a combined rail access (feeder) and local access (community- and activity-center-based) transit service.

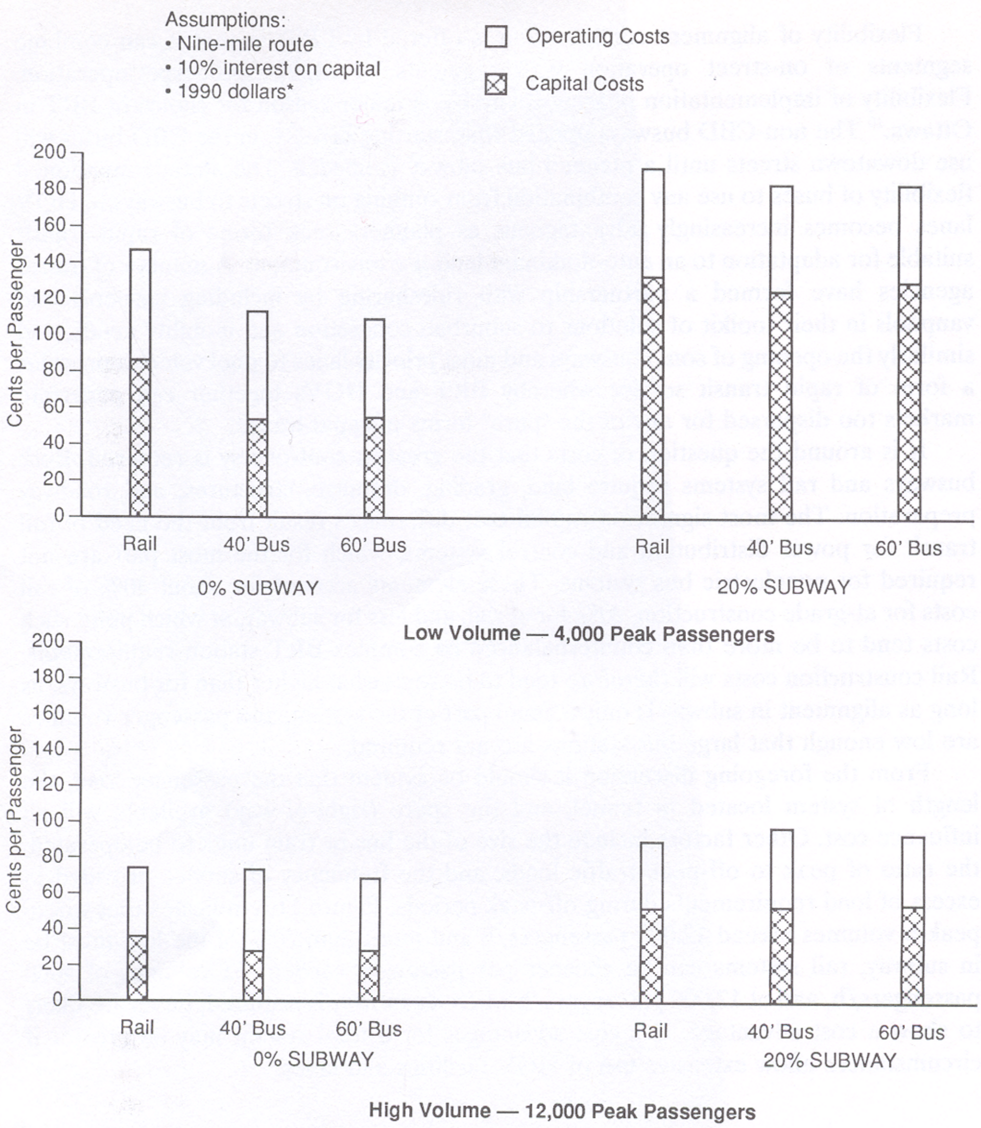
Flexibility of alignment configuration is offered by LRT, in that it can combine segments of on-street operation with segments of rapid-transit-type operation. Flexibility of implementation phasing is cited as a major reason for choice of BRT in Ottawa.10 The non-CBD busways opened first, starting in 1983; in the CBD buses will use downtown streets until a planned bus subway is needed. The already mentioned flexibility of buses to use any combination from running on streets to busways to HOV lanes becomes increasingly advantageous as planners seek forms of rapid transit suitable for adaptation to an auto-dominant land-use environment. A number of transit agencies have formed a partnership with ridesharing by including carpools and vanpools in their toolkit of solutions to suburban congestion and mobility needs, and similarly the opening of some busways and most priority lanes to pool vehicles provides a form of rapid transit service whereby BRT and HOVs together can penetrate markets too dispersed for any of the "pure" forms of rapid transit.

It is around the question of costs that the greatest controversy is centered. Both busways and rail systems require land, grading, drainage, structures, and roadway preparation. The most significant capital cost differences result from the need of rail transit for power distribution and control systems, which for the most part are not required for nonelectric bus systems. These elements account for about 40% of rail costs for at-grade construction, 20% for aerial, and less for subway, at which point such costs tend to be more than counterbalanced by complex BRT station requirements. Rail construction costs will therefore tend to be somewhat higher than for busways, as long as alignment in subway is only a small part of the system, and passenger volumes are low enough that large bus stations are not required.

From the foregoing discussion it should be evident that the passenger load, the length of system located in tunnel, and the space (right-of-way) available will all influence cost. Other factors include the size of the bus or train units to be operated, the ratio of peak to off-peak traffic loads, and the frequency of service provided in excess of load requirements during off-peak periods. Figure 11-6 indicates that where peak-h volumes exceed 12,000 passengers/h and more than 20% of the line must be in subway, rail systems can be cheaper per passenger carried. At volumes of 4000 passengers/h, and at 12,000 passengers/h when no subway is required, buses are likely to show a cost advantage. Bus cost advantages for a total system may be greater if circumstances allow extensive use of HOV facilities and lanes.

HOW TO EVALUATE

Decision makers faced with questions of "whether to build" and "which technology" have the opportunity to make use of evaluation procedures that have been continuously evolving over the last several decades. The evolution has progressed through cost-benefit analysis into the present use and continued development of both effectiveness analysis and alternatives analysis with its cost-effectiveness measures.



* In converting to 1990 dollars, no attempt has been made to introduce the effects on capital cost of environmental, handicapped accessibility, or other requirements or trends since the original study. The costs per passenger are thus lower than current experience, but are valid in relative terms for purposes of rail versus bus comparison.

Figure 11-6 *Total rail and busway costs (cents/passenger). [Source: Compiled by William G. Allen, Jr., for the Transportation Research Board; adapted from Thomas B. Deen and Donald H. James, "Relative Costs of Bus and Rail Transit Systems," in* Transportation Systems Planning, *Highway Research Record 293 (Washington, D.C.: Highway Research Board, 1969), p. 52.]*

Alternatives analysis and associated systems and project development planning steps are at present required for almost all rapid transit projects receiving federal capital funding in the United States.

COST BENEFIT ANALYSIS

Economic analysis has long been an important element of determining the feasibility of large capital-intensive projects. Historically, such examinations have attempted to measure the magnitude of total benefits expected to accrue over the entire life-cycle of the project compared to its total costs, a process often called cost-benefit analysis. Both benefits and costs expected in the more distant future are heavily discounted compared to short-term effects. In the application of cost-benefit analysis to a rapid transit project, the costs include the one-time costs of land acquisition and system construction as well as the continuing costs of system operation. Benefits include time savings of the passengers of the preexisting transit service, operating cost and/or time savings of passengers who otherwise would have used private cars or other modes of travel, and any time savings estimated for those choosing to remain in their cars but projected to experience less congestion.

Cost-benefit analysis is an effective way to compute and compare those costs and benefits that can reasonably be translated into monetary terms. Urban goals of the late twentieth century, however, have been increasingly oriented toward values that are difficult if not impossible to measure monetarily. For example, determining the dollar value of increasing the mobility of the poor or of encouraging particular land-use patterns, or of reducing air pollution is a daunting task. Such calculations must necessarily depend on some heroic and less than totally agreed on assumptions.

The benefits that the rapid transit cost-benefit analyses of the 1960s and 1970s attempted to encompass can be divided into three categories:

1. *Transportation (direct) benefits.* Includes travel-time and operating cost savings for various classes of users of the transport system (all modes).

2. *Community (indirect) benefits.* Includes those other benefits deemed by the analysts to be quantifiable but stemming from secondary effects of the transportation improvement.

3. *Miscellaneous benefits.* Includes items not conveniently classed into the other two categories.

A critical evaluation of cost-benefit analysis as applied to rapid transit, prepared in 1975, concluded that, while the direct benefits included in the various studies were relatively uniform in concept and in components included, indirect benefits varied widely, with seemingly little agreement as to what items to include and what methodologies to employ, and the miscellaneous benefits included seemed to represent further departures from rigorous cost-benefit methodologies.11 In the face of such analytical disarray, transportation planning professionals called for critical study elements to be prescribed and standardized.

Examples of problem areas identified in various cost-benefit analyses included double counting within direct benefits by including both accident and insurance cost reductions probable multiple counting within indirect benefits involving different ways of measuring the same benefit, and selection of inappropriate bases for comparison in computing benefits such as “savings from transport investments no longer needed." "Savings in fare expenditures" were often treated as benefits but are simply revenue reductions, and should have been excluded, since system revenue is neither a benefit nor a cost but a component of system financing. "Savings in bus system operation costs" should have been regarded as a reduction in system cost (to be found in the denominator of the benefit-cost ratio) instead of as a benefit (in the numerator).

As part of the critical evaluation, benefits from several studies were converted to constant (1973) dollars and normalized by dividing the benefits by the number of transit system riders that had been estimated for the design year. Even the direct benefits per rider were found to vary widely in value. Operating cost savings by persons estimated to divert to the improved transit system varied from over $6.90 for Honolulu and Los Angeles to only $0.74 in Atlanta. Time savings for trips that continue to use autos after transit improvement, attributed to estimated reduction in highway congestion, varied from Honolulu's $16.14 down to Baltimore's $0.40. Table 11-5 summarizes the values and direct benefit percentages estimated for different cities.

The absolute value of total benefits per design-year rider varies from Baltimore's $41.34 down to Buffalo's $4.86. It is difficult to explain why there should be a tenfold difference. The proportion of all benefits that were related to direct transportation benefits varies even more, from more than 100% in Buffalo and Honolulu to only 36% in Baltimore. The table also suggests some of the reasons for the wide variations encountered. The *discount rate*, the presumed time value of money used to discount the value of future benefits and costs back to present worth, is a critical assumption used in cost-benefit analysis and can make a big difference in the results when comparing systems with different degrees of capital intensiveness. This value varied from 4% in Buffalo to 6% in Atlanta. The value of travel-time savings varied from $0.60 to $3.60 per hour.

Clearly, the relative value of rapid transit systems could not even be hinted at when the input assumptions were so variant. Economic analysis of benefits and costs fell into disfavor in the United States, partly because of the lack of standards (an open invitation to add benefits from as many sources as imagination could produce), partly because of the necessary dependence on a number of difficult and therefore frequently questioned assumptions, and partly because of attempts by authorities to bend the process into a tool for justifying actions they fervently desired to take for various reasons. Although the cost-benefit analyses of the 1960s and 1970s are now history, the lessons learned are invaluable, and many of the more desirable attributes of cost—benefit analysis are systematized and included in evaluation methodologies described in the following sections.

TABLE 11-5

Selected Differences in Benefit/Cost Assumptions and Corresponding Total Benefits Estimates

Metro Area	Discount Rate (%)	Value of Time ($/hour)	Direct Benefits as %of Total	Total Benefitsper Design-Year Rider (1973 dollars)
Buffalo	4	1.72	119	4.86
Atlanta	6	3.00	98	24.85
Baltimore	4	0.60	36	41.84
Honolulu	5	3.19	113	33.63
Los Angeles	6	3.60	62	31.88
Washington	4	2.95	98	13.03
Cleveland	6	2.80	66	13.82

Source: Adapted from Thomas B. Deen, Walter M. Kulash, and Stephen E. Baker, "Critical Decisions in the Rapid Transit Planning Process," in *Transit Planning,* Transportation Research Record 559 (Washington, D.C.: Transportation Research Board, 1976), pp. 33-43

EFFECTIVENESS ANALYSIS

The inability of cost-benefit analysis to address nonmonetary factors led to the utilization of what is called effectiveness analysis or goal attainment evaluation. Introduction of effectiveness analysis did not necessarily require new analytical techniques, although it tended to encourage them; it was and is primarily a means of organizing and dealing with analytical results. It is a systematic procedure for examining the relative merits of different transportation proposals in a manner that allows taking into account important concerns not encompassed by cost-benefit analysis. When the proposals examined include transportation options without rapid transit and options with alternative rapid transit modes, effectiveness analysis directly addresses both the "whether to build" and "which technology" questions.

Effectiveness analysis allows all types of evaluation measures: (1) those that can be meaningfully described in monetary terms, (2) those that are not meaningful in monetary terms but can be quantified in other units, and (3) those that, while important, can only be described qualitatively. Cost-benefit types of measures are not excluded from effectiveness analysis. They can be included as part of the broader evaluation provided by the methodology.

The steps necessary to carry out an effectiveness analysis are:

1. Explicit definition of *goals* (generalized end states or directions of desired movement), *objectives* (specific end states or targets to be hit), *criteria* (ways to measure objective attainment), *measures* (attributes to be tested to determine the degree of objective attainment), and, if applicable, *standards* (acceptable levels of objective attainment).

2. Assembly of forecasts, estimates, and other analysis results into an evaluation matrix, relating the analysis findings to the evaluation criteria used and to the different alternatives examined.

Table 11-6 illustrates one example each of a number of possible goals, objectives, and criteria, along with associated measures. Figure 11-7 illustrates an evaluation matrix. Criteria that are measured in monetary units, quantitative nonmonetary units, and qualitative terms are separately identified.

TABLE 11-6

Example Goal, Objective, Criterion, and Measures

Goal:	Quality transit service competitive with the auto
Objective:	To provide a high level of transit service from trip origin to trip destination
Crierion:	Door-to-door transit travel time, convenience and reliability for corridor travel
Measures:	Peak-period and off-peak in-vehicle transit travel time between residences and CBD Number of transfers required between residences and CBD Peak-period and off-peak service frequency for collector and trunk-line transit service Amount of corridor dwelling units within walking distance of stations or stops Amount of corridor employment within walking distance of stations or stops Segregation of transit vehicles from traffic delays

The extensive inclusion of highway performance measures within the evaluation matrix of Fig. 11-7 would be inappropriate for a purely rapid-transit evaluation. The evaluation matrix is from the 1989-1990 *Commuter Assistance Study* of the Maryland Department of Transportation, a new breed of multimodal study that simultaneously evaluates not only alternative rapid transit modes, but also all kinds of highway and HOV improvements along with low-cost transit options.12 Such multimodal evaluations may become more common in the future in light of efforts within the U.S. Department of Transportation (DOT) to achieve better consistency and coordination between the capital project evaluation processes of the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration.

When effectiveness analysis began to supplant cost-benefit analysis, the pendulum swung away from economic assessments, exposing a potentially major weakness. While the many evaluation measures of effectiveness analysis may be of great assistance in the local determination of whether to build rapid transit or not and in the choice of rapid transit mode, they may obscure the economic deficiencies of those proposals that should rank as "crazies" and do not necessarily provide a simple indicator for use by senior governments faced with prioritization needs. Thus, while UMTA encourages the use of effectiveness analysis techniques in the systems analysis process and the choice of a locally preferred alternative, it mandates as part of its alternatives analysis process the development of a specific economic measure that can be compared from project to project. One way to strengthen effectiveness analysis is to make sure that one or more such economic measures are included in the evaluation matrix.

Measures of the Problem/Solution	Existing Conditions	Future Null Alternative	Alternative 1	Alternatives 2, 3 . . .
Screen-line highway volume/capacity ratio	####	####	####	####
Percentage of highway lane-miles operating at LOSs A-F	####	####	####	####
Person-miles traveled via LOV, HOV, transit	####	####	########	
Transit boar dings	####	####	#####	####
Percentage of commuter miles carried via LOV operating at or above LOS D; via HOV; via transit	####	####	####	####
Travel times for selected locations	####	####	####	####
Reduction in highway VMT	NA	NA	####	####
Capital cost	NA	NA	$$$$	$$$$
Annual operating cost	NA	NA	$$$$	$$$$
Annualized cost per transit trip	NA	NA	$$$$	$$$$
Ability for transit to meet specified cost/revenue ratio	NA	NA	========	
Enhancement of access to existing or planned economic development	NA	NA	====	====
Compatibility with local transporttation plans	NA	NA	========	
Fatal flaw evaluation	NA	NA	====	====
Right-of-way opportunities	NA	NA	====	====
Other issues including safety	NA	NA	====	====

Legend: LOV Low-occupancy vehicle. HOV High-occupancy vehicle.
LOS Level of service. VMT Vehicle miles of travel.
44444 Measure described quantitatively in nonmonetary terms (e.g., travel time).

Measure described quantitatively in monetary terms (e.g., millions of dollars).
Measure described in qualitative terms (e.g., good/fair/poor).
NA Not applicable to evaluating base case conditions.

Figure *11-7 Multimodal Alternatives Evaluation Matrix. [Source: Adapted from COMSIS Corporation, Parsons Brinckerhoff Quade & Douglas, and Richard H. Pratt, Consultant, Inc.,* Maryland Statewide Commuter Assistance Study Corridor Profile Reports, prepared for *Maryland DOT (Baltimore-Washington International Airport, Md.: Maryland Department of Transportation, 1990).*

Whether or not a formal effectiveness analysis is conducted as part of the evaluation process, formulation of transportation goals and objectives is a step that should not be omitted for any city considering investment in rapid transit. These goals and objectives need to be comprehensive and specific, avoiding vague "motherhood and apple pie" protestations. Goals and objectives are the mechanism whereby regional and local decision makers can guide planners and engineers toward achieving the desired ends and can then check (using the evaluation results) that the desired ends are in fact best served by the solutions offered.

ALTERNATIVES ANALYSIS

In the mid-1970s, with cost-benefit analysis of rapid transit proposals in growing disrepute, it was suggested that the U.S. DOT should require studies of rapid transit feasibility to meet prescribed standards prior to application for federal funds. The U.S. DOT and UMTA themselves strongly felt this need, given their responsibility for equitable and politically defensible distribution of federal funding. UMTA's response has been their "Major Capital Investment Policy," which in turn is embodied in the UMTA "Major Capital Investment Planning" process.13

This policy and process is not intended to be a substitute for a region's own comprehensive planning. The cost-effectiveness measures prescribed are the product of a limited goal set oriented toward rating projects for suitability of federal funding in an era of scarce federal resources. Nonetheless, the major capital investment process, including environmental analysis requirements linked with it, has influenced planning well beyond that done in support of applications for U.S. federal funds. The key UMTA major capital investment policy tenets are (abridged):

- Proposed guideway projects shall be consistent with the area's comprehensive long- range transportation plan.

- Where the plan calls for a fixed guideway, it should be proposed for implementation incrementally, one usable segment at a time.

- Projects must be cost effective as determined through an analysis of transportation alternatives, including low-cost improvements to the existing infrastructure and better management and operation of existing transportation facilities.

- There should be full opportunity for the timely involvement of the public, local elected officials, and all levels of government in the alternatives analysis process.

- Project decisions should be based upon realistic cost estimates and financing proposals that take into account operating expenses.

- The local area should consider local supportive actions to enhance cost effectiveness, including land-use planning, zoning, joint development, feeder bus services, adequate parking, and other pricing, regulatory and enforcement measures.

The UMTA major capital investment project development process encompasses

(1) system planning, (2) alternatives analysis, (3) preliminary engineering, (4) final design, and (5) construction. The system planning and alternatives analysis phases are where "whether to build" and "which technology" questions are normally resolved, but decisions may be changed during preliminary engineering as well, as more refined costs and other information become available. The system planning phase is viewed as being integrated with the ongoing urban transportation planning process during which local officials update regional goals and objectives, project future land use and travel, identify current and anticipated transportation problems, examine a wide range of alternative solutions, assess the availability of financial resources for future capital and operating costs, and develop short- and long-range implementation programs reflecting financial resources. UMTA equates system planning with the ongoing 3C urban transportation planning process (see Chap. 3) conducted in each urbanized area by its metropolitan planning organization, but equivalent planning processes can occur at the state level. For example, the Maryland DOT intends to transition its previously mentioned *Commuter Assistance Study* into such an ongoing process covering all transportation modes statewide.

The alternatives analysis phase may be initiated if local officials find that one or more corridors in the region are candidates for fixed-guideway transit investments. They select a priority corridor and identify a small set of potentially cost-effective alternatives for detailed study. Upon receiving approval to initiate an alternatives analysis, the designated local lead agency studies the priority corridor in detail, looking at alternative solutions to the transportation problems identified in system planning. For each alternative, estimates are prepared of measures of transit service quality, patronage, farebox revenues, operating and maintenance costs, and operating deficits; station access and parking impacts, highway congestion effects, and any other transportation system impacts; environmental impacts; capital costs; and financial requirements. The analysis is brought together in a comparative assessment of the benefits and costs of each alternative, essentially an effectiveness analysis.

The range of alternatives analyzed will typically include one or more rail rapid transit options (RRT, LRT, or other fixed guideway) and a BRT alternative, often with provisions for joint use with other HOVs, and must include both a null (no-action) alternative to meet National Environmental Policy Act regulations and a nonguideway bus/transportation systems management (TSM) alternative. This TSM alternative includes such low-cost actions as traffic engineering and transit operational changes, along with significant (but not major) capital improvements as appropriate, all accomplished within realistic limits imposed by such constraints as street capacity and funding for operating deficits. The TSM alternative is intended in part to place cities competing for U.S. federal funds on a level playing field, recognizing that existing conditions will vary from city to city in the amount of TSM that has already been accomplished. It is also designed to demonstrate the extent to which transportation problems can be resolved without recourse to a major investment in new facilities, thereby providing technical findings relevant to the "whether to build" decision. Analysis of the other alternatives provides information for the "which technology" decision.

The alternatives analysis phase includes the development of a draft environmen.

impact statement, selection of what UMTA calls the locally preferred alternative, and preparation of a realistic funding plan. Lest the earlier discussion of financial, institutional, and attitudinal factors makes it seem that this comprehensive and involved process may be no more than an expensive and contrived justification of decisions already made, it should be pointed out that—at the very least—a properly done alternatives analysis, in addition to guarding against a major mistake, can provide a wealth of highly useful information pertinent to rapid transit alignment choice, station and terminus location decisions, determination of local bus service policy, and design of distributor, feeder, and complementary transit routings.

A crucial element of alternatives analysis, particularly from the federal perspective, and the element most subject to criticism is the computation of cost effectiveness. Along with local financial effort, the cost-effectiveness measure is the primary nonpolitical determinant of priority for federal funding. *Cost effectiveness* means the extent to which a project returns benefits relative to its costs. In an UMTA alternatives analysis, the cost effectiveness of a rapid transit project is measured in terms of its added benefits and added costs when compared to the TSM alternative. The cost-effectiveness measure initially prescribed by UMTA, one of two accepted cost effectiveness measures as of 1990, is called the incremental index. The *incremental index* takes the form

$$\text{Incremental Index} = \frac{\Delta\$CAP + \Delta\$O\,\&\,M + \Delta\$TT}{\Delta RIDETRS} \qquad (11\text{-}1)$$

where A = difference relative to the TSM alternative
$CAP = total capital costs, annualized over the life of the project
$0&M = annual operating and maintenance costs
$TT = annual value of travel time for existing riders
RIDERS = annual transit ridership, measured in linked trips

The lower the index is, the better the project. Note that the denominator, being the difference in ridership relative to the TSM alternative, causes the measure to place a very high value on the attraction of new transit riders, thereby acting as a surrogate for the intangible benefits associated with reduced automobile use. The other potential benefit included in the equation, reduced travel time for existing riders, is expressed as a negative cost when there are time savings. UMTA specified values of time in 1984 of $4.00/h for work-purpose trips and $2.00/h for other trips. The plan is to update these values as conditions require.

The second cost-effectiveness measure accepted by UMTA uses consumer surplus as the benefit measure, expressed in terms of hours of user benefits. The corresponding cost- effectiveness equation, known as the *user index, is*

$$\text{User Index} = \frac{\Delta \$CAP + \Delta \$O\,\&\,M}{\Delta USERBENFITS} \qquad (11\text{-}2)$$

where A = difference relative to the TSM or other less expensive alternative/$CAP = total capital costs, annualized over the life of the project

$0&M = annual operating and maintenance costs

and A USER BENEFITS are calculated in hours, in a manner based on micro-economic theory, according to Eq. (11-3).

$$\Delta USERBENEFITS = [(p_0 - p_1) * R_0 + [\frac{(p_0 - p_{1)}}{2} * (R_1 - R_0)] \qquad (11\text{-}3)$$

where *Po* = price of travel paid by TSM or other base-case riders
P1 = price of travel for the same trips with further investment
Ro = number of TSM or other base-case riders
R1 = number of riders with further transit investment

Price of travel in this context includes travel time, fares, and charges at park-and-ride lots, all the time and out-of-pocket costs incurred by the transit user. The price of in-vehicle travel time is as measured, expressed in hours. The price of out-of-vehicle travel time is calculated, borrowing a relationship derived from transit ridership forecasting (mode choice models) by weighting the measured walking, waiting, and transferring time by a factor of 2. The price of fares and other charges is expressed in hours using values of time to convert from dollars. The units of the user index cost-effectiveness measure thus are dollars per hour, in other words, the amount of expenditure it will take to achieve an hour of travel-time savings or equivalent benefit. Required expenditures out of scale with prevailing wage rates should raise a red flag, suggesting the need for extra scrutiny of the transit investment involved.

Table 11-7 summarizes five case studies presented by Samuel Zimmerman to illustrate how the investment rating system developed by UMTA has worked. Of the five proposals, the Seattle Bus Tunnel, Houston Transitways, and Los Angeles Metro Rail are projects that were highly rated as potential federal transit investments, whereas the St. Louis LRT and Miami Downtown People Mover (DPM) extension are projects that did not fare well in the rating process, although they later did receive funding by the U.S. Congress. Common features of the highly rated projects are that they are generally a critical piece of a much larger system, the benefits are substantially higher than the level that could be achieved with more modest investment (as exemplified by the TSM alternative), and they are backed by stable and dependable local financing of transit. Contrasting common features of the poorly rated projects are their inability to produce significant incremental transportation and other benefits over more modest investments and the precarious state of local transit financing.14

TABLE 11-7
Five UMTA Major Investment Rating System Case Studies

Project	Total Cost (millions)	UMTA Share (millions)	Incremental Index (per trip)	Local Fiscal Effort: Nonfederal Share (%)	Local Fiscal Effort: Capital Financing Plan	Local Fiscal Effort: Reliability of Operating Assistance
Seattle Bus Tunnel	$394	$179	$1.44	50	acceptable	acceptable
Houston Transitways	$356	$210	$3.78-4.94	40	acceptable	acceptable
L.A. 8-mi Metro Rail	$1250	$696	$330	44	acceptable	acceptable
St. Louis LRT	$384	$289	$9.50	25	no cash match	deficient
Miami People Mover Extensions	$248	$186	$15.20	25	acceptable	deficient

Source: Adapted from Samuel L. Zimmerman, “UMTA and Major Investments: Evaluation Process and Results," in *Transit Administration and Planning Research,* Transportation Research Record 1209 (Washington, D.C.: Transportation Research Board, 1989), pp. 32-36.

The alternatives analysis evaluation processes are not without problems. Systems covered by alternatives analyses and earlier economic analyses are now in operation, and some analysts have concluded that the underlying estimates upon which the original evaluations were based have tended to be decidedly optimistic. A review by Don Pickrell covering ten federally funded projects, summarized in Table 11-8, suggests that actual ridership results have ranged from 28 to 85% lower than the forecasts available when the "whether to build" decision was made. Taken in combination with capital cost experience averaging 50% above estimates and operating costs even further in excess, the annual capital and operating cost per passenger has been calculated as running from almost 3 to almost 10 times the originally estimated value in constant dollars.15

Such findings raise the possibility that decision makers might have made different choices if more accurate forecasts were available and underscore the importance of steps to improve the accuracy of forecasts prepared to support future transit investment decisions. The temptation to overestimate ridership and underestimate costs is strong during the planning phase. However, operating cost estimation should now have benefited from actual experience with running automated systems, and ridership estimation procedures have improved, particularly in the representation of transit usage by those beyond walking distance of transit service. Likewise, the capital cost estimation procedures applied in U.S. planning ought now to reflect previously unforeseen obstacles to cheap construction, such as environmental impact mitigation requirements, handicapped accessibility requirements, and requirements resulting from the NIMBY (not in my back yard) syndrome, coupled with the litigious nature of our citizenry, all likely contributors to the increase in constant-dollar costs from the 1950s and 1960s to the 1970s and 1980s clearly seen in Figs. 11-3 and 11-4.

Caution is required in the application of hindsight. For example, attempts to evaluate performance by recalculating the UMTA incremental index with systemwide ridership data obtained before and after the opening of new systems are particularly problematic. The results have been highly variable, and if, for whatever reason, systemwide transit ridership declined as the guideway system was introduced, no cost per new transit trip can be computed at all. Some such situations, as has been inferred, may occur because the new system performed poorly. In other cases, the cause may be exogenous factors such as local economic conditions (for example, economic recession) and systemwide transit service and fare changes (for example, fare increases). Transit systems reported to have lower ridership in some period after guideway implementation have included not only certain U.S. operations with UMTA-funded rail lines, but also at least one LRT and the Ottawa busway[16] from among the heavily used Canadian systems.

Concerns about decisions made on the basis of faulty estimates come closest to the mark in the cases where the discrepancy is greatest, such as Miami. One would have to know a system's performance relative to the broader range of regional goals and objectives to make full judgment. Even though past forecasting has been highly imperfect, it would be unwise to reject economic analysis and related measures outright. Consider case examples from the planning of Washington's Metrorail. During planning, a number of transportation professionals and political leaders were concerned that a new system in the automobile age could never carry as many riders as the established RRT systems in cities such as Chicago, Philadelphia, and Boston. The forecasts, however, given Washington's unique travel patterns, projected that Metrorail would generate more ridership. It now does so. There were other critics who thought the system needed express and local tracks, like New York's. The forecasts projected that Washington Metrorail would carry only a fraction of New York's RRT ridership, and that is also the case. Thus transportation planning analysis allowed major issues to be put in the proper context.

There are technical difficulties with the UMTA cost-effectiveness measures to consider. Experience has shown that the incremental index has these deficiencies:

- The use in the denominator of "new transit trips," a number derived by subtracting one forecast from another, makes the index statistically volatile and highly sensitive to forecasting errors of the type cited by Pickrell.
- Benefits to existing riders are valued in the dollar equivalent of travel time saved and subtracted from costs inconsistent with the treatment of benefits to new riders, which are valued simply in numbers of new transit trips.
- Although many benefits are related to the attraction of new transit trips, the measure does not address such factors as the length of trips served.
- The index cannot be used for all modes in a multimodal study; even the introduction of HOV facility components creates "new trip" definitional problems.

The consumer surplus cost-effectiveness measure was developed to address some of these problems, however, there seem to be two criticisms applicable to this index:

TABLE 11-8
Forecast and Actual Results for Recent Rail Projects

Rail Rapid Transit Projects Light Rail Transit Projects Downtown People
Mover Projects
Washington Atlanta Baltiimore Miami Buffalo Pittsburgh Portland Sacramento Miam
Detroit

Weekday Rail Passengers (thousands)

Forecast j69.6 Nfa 103.0 239 9 92.0 90.5 42.5 50.0 41.0 67.7
Actual 411.6 1845 42.6 35A 292 30.6 19.7 14.4b 10.8 11.3

Difference -28% _ -59% -85% -68% -66% -54% -71% -74% -83%

Rail Project Capital Cost (millions of 1988 dollars)

Forecast 4352 1723 804 1008 478 699 172 165 84 144
Actual 7968 2720 1289 1341 722 622 266 188 175 215

Difference 83% 58% 60% 33% 51% -11% 55% 13% 106% 50%

Annual Rail Operating Expense (millions of 1988 dollars)

Forecast 663 13.2 NF 265 10.4 NF 3.8 7.7 25 7.4
Actual 199.9 403 21.7 375 11.6 8.1 5.8 69 4.6 109
Difference 202% 205% _ 42% 12% - 45% -10% 84% 47%

Total Annualized Cost Per Annual Rail Passenger (1988 dollars)

Forcast 3.04 NF NF 1.73 2.15 NF 1.68 153 0.90 1.14
Actual 8.75 5.93 12.92 16.77 1057 794 5.19 653 701 10.21
Difference 188% _ _ 872% 392% - 209% 328%
693% 795%

aNF = not forecast
bSacramento daily LRT patronage is reported to be 23,000 in 1990.

Source: Don H. Pickrell, *Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs* (Washington, D.C.: Urban Mass Transportation Administration, 1989), p. Vii.

- The computation of benefit includes fares and other user fees. As in the case of cost-benefit calculations, user-fee savings to the transit riding public have to be counterbalanced by higher subsidy by the public at large and therefore should not be a part of benefit computations.

- The benefit assigned to a new transit rider, being calculated on the basis of travel time and user-fee savings alone, is one-half the benefit assigned to an existing transit rider making the same trip and cannot serve as a surrogate for indirect benefits such as congestion reduction or reduction in pollutant emissions.

It is arguable that the travel-time savings benefit in the user index does serve as an adequate proxy for such indirect or miscellaneous benefits as mobility enhancement and economic development in the user index. The first of the two criticisms can be addressed by simply leaving saving in fares and other user charges out of the benefit equation. The second can be addressed by recognizing that the incremental cost-effectiveness measure should not be used in isolation, but rather in conjunction with other measures in a comprehensive evaluation such as encompassed by effectiveness analysis.

Clearly, economic analysis is not a substitute for good sense; the judgment of those involved in the decision making must be relied upon to weigh the relative importance of cost effectiveness and nonmonetary factors. It would seem, however, that effectiveness analysis, including the use of quantitative economic criteria and full consideration of alternatives, is a good way to approach rapid transit evaluation. If U.S. federal money is sought, then the planning process may require some adjustment to ensure compliance with mandated UMTA alternatives analysis requirements. This is not to say that there is anything intrinsically superior, from the local decision-making point of view, with the UMTA process. Nevertheless, low cost effectiveness should serve as a warning that nonmonetary benefits must be extremely important if such a system is to be justified.

SUMMARY

Decisions of whether to build rapid transit and which technology to adopt take place in a dynamic political and institutional environment that makes evenhanded evaluation difficult. When officials responsible for building a system must get voter support for bond issue financing, the support must come from the entire area if they are to build anything. The amount of investment then is a function of what it costs to cover the area, and, in such an environment, investment analysis becomes foreign.

The cost and effectiveness of providing rapid transit is determined in a major way by urban area configuration and availability of rights-of-way. Arguments about the relative costs of rail rapid transit and bus rapid transit are seen to be transcended by the cost implications of more complex decisions about whether the system—whatever the technology—must be underground, elevated, or on the surface.

Public acceptance tends to lean toward rail systems, even when bus systems might serve better for less cost. Bus rapid transit cost advantages may be enhanced by opportunities for taking advantage of high-occupancy vehicle facilities and lanes. Otherwise, the differences between costs of rail and busway systems are not as great as is often supposed. Many times the decision will have to be made on factors other than cost.

Evaluation procedures are imperfect, but honest attempts to develop sound, objective, and instructive information can contribute greatly to informed choices. A properly done alternatives analysis or comparable economic and effectiveness assessment will first and foremost help guard against a truly bad public investment decision. The required evaluations also provide highly useful direction as to the location and design of the high-cost guideways, stations, and appurtenances of any rapid transit that may be decided upon.

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EXERCISES

11-1 Identify three major influences that effect the decision of whether to build rapid transit in U.S. cities. Which of these do you think are most important? Why?

11-2 Name several factors that tend to argue for beginning rapid transit with a single line. What factors argue for an initial commitment for a full regional system?

11-3 What factors are most important in determining the likely patronage, cost, and cost effectiveness of rapid transit in a regional corridor?

11-4 Why has rapid transit not been used for non-CBD-oriented corridors? What factors tend to limit the utility of rapid transit for intrasuburban travel?

11-5 What attributes of commuter railroads preclude their use in all but the largest U.S. cities, and not all of those?

11-6 Which of the newer rapid transit systems have total costs per passenger mile significantly exceeding the cost range for travel by auto and local bus?

11-7 What justification might there be for building such systems? In hindsight, what decisions might you have made on whether or not to build rapid transit and what technology to select? Why?

11-8 Assume you were given the task of evaluating a new rapid transit proposal. Develop an evaluation process including goals, objectives, criteria, and measures.

11-9 What do you consider to be the appropriate division of roles between transportation planners and politicians in rapid transit evaluation and development?